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MEASURES TO REDUCE URBAN AIR POLLUTION IN WARTIME CONDITIONS ON THE EXAMPLE OF DNIPRO CITY

The research analyzes the realities and challenges of air pollution reduction in urban areas under wartime conditions, using Dnipro City as a case study. Extraordinary factors, such as explosions, fires, and increased industrial emissions, contribute to the worsening air quality. The study identifies primary and secondary pollutants, emphasizing their transformation into toxic derivatives and their synergistic impacts on human health and ecosystems. Special attention is given to the role of motor vehicles, noise, and infrasound pollution, which exacerbate environmental and public health issues. The paper highlights specific mitigation strategies, such as strict monitoring of industrial emissions, control over urban transport emissions, and the reduction of fine dust and allergenic plant influences. Proposed measures aim to minimize immediate health risks and lay the groundwork for future air quality management strategies in post–war recovery.

***Keywords**: air pollution; wartime conditions; secondary pollutants; synergistic effects; noise pollution; mitigation measures; Dnipro City; environmental health.*

У дослідженні проаналізовано особливості та виклики зменшення забруднення повітря в умовах воєнного стану на прикладі міста Дніпро. Надзвичайні фактори, такі як вибухи, пожежі та підвищені промислові викиди, посилюють забруднення повітря. Визначено первинні та вторинні забруднювачі, підкреслено їхню трансформацію у токсичні похідні та синергічний вплив на здоров’я людей і екосистеми. Окремо розглянуто роль автомобільного транспорту, шумового та інфразвукового забруднення, що поглиблюють екологічні й санітарні проблеми. У роботі запропоновано конкретні заходи зменшення забруднення: контроль промислових вики-

дів, обмеження шкідливих транспортних викидів, боротьба з пилом та алергенними рослинами. Запропоновані заходи спрямовані на мінімізацію нагальних ризиків для здоров'я та створення підґрунтя для подальшого управління якістю повітря у період відновлення після війни.

Ключові слова*: забруднення повітря; воєнний стан; вторинні забруднювачі; синергічний вплив; шумове забруднення; заходи зменшення; місто Дніпр; екологічне здоров'я.*

Problem's Formulation

Air quality management in the Dnipro agglomeration under the extraordinary conditions of the war in Ukraine is a task whose solution is associated with a number of environmental problems, taking into account the following.

The Dnipro agglomeration, even in peacetime, had a very high degree of air pollution, as evidenced by environmental passports and reports of the Ministry of Ecology for the past peaceful years [1].

The air environment is capable of transboundary transfer of pollution. At the same time, harmful and toxic components formed from explosions, burning or smoldering of oils, fuels, various materials, landfills, as well as during fires (including forest and steppe fires), spread very quickly from their sources to adjacent territories. Therefore, in urban areas, problems related to combined and secondary air pollution arise or are exacerbated, which cannot be ignored.

Analysis of recent research and publications

The peculiarities of the formation and transformation of anthropogenic pollutants are described in [2]. The author emphasizes the importance of understanding the interrelation between humans and the environment, drawing attention to the processes by which primary pollutants evolve into more complex secondary forms. It is noted that environmental contamination is a dynamic system, where human activity continuously alters natural chemical balances and the self–regulation capacity of ecosystems.

In [3], the principles of ecological toxicology are examined in detail. The authors analyze the mechanisms through which pollutants penetrate biological systems and accumulate in living organisms, forming long–term ecological and physiological consequences. The publication also highlights that many derivatives of primary pollutants become more toxic during biochemical and physicochemical transformations, thus increasing their persistence within environmental components.

The work [4] presents scientific and practical approaches to air protection. The authors focus on monitoring and control methods for industrial emissions, emphasizing the necessity of integrating preventive strategies into environmental management. The study notes that secondary pollution, resulting from the interaction between anthropogenic and natural compounds, often creates unpredictable "chain reactions" that enhance the cumulative impact of harmful substances on the atmosphere.

In, the concept of ecological engineering in urban development is discussed as a means to mitigate air pollution and improve environmental safety. The authors provide examples of applying engineering and architectural solutions to minimize the concentration of harmful emissions in densely populated areas. They also stress that urban air quality depends not only on technological innovation but also on the ability to maintain ecological balance through sustainable design principles.

Overall, sources [2—4] collectively outline the theoretical foundations and applied aspects of air environment protection, emphasizing the role of transformation processes, bioaccumulation, and ecological engineering in mitigating anthropogenic impacts. The reviewed works confirm that modern environmental science increasingly relies on an integrated approach that combines ecological monitoring, toxicological assessment, and sustainable urban planning.

Formulation of the study purpose

The main purpose of this study is to analyze the types, sources, and transformation processes of air pollutants and to assess their influence on the environment and human health. The study also aims to evaluate how noise and infrasound pollution affect the human body and to highlight the need for integrated approaches to minimize environmental risks.

Presenting main material

Primary air pollutants include substances directly emitted into the atmosphere from natural and anthropogenic sources, such as sulfur dioxide, nitrogen oxides, carbon monoxide, and particulate matter. Secondary pollutants, including ozone and acid rain, are formed through complex photochemical reactions between primary pollutants. Their accumulation leads to significant changes in atmospheric composition, ecosystem imbalance, and health risks for living organisms.

Noise and infrasound pollution, often underestimated, also significantly affect human physiological and psychological conditions. Long–term exposure to elevated noise levels may result in cardiovascular, nervous, and endocrine system disorders. Infrasound, though less perceptible, can cause chronic fatigue, irritability, and impaired concentration.

The transformation of pollutants in the environment involves chemical and physical processes that may either enhance or reduce their toxicity. For instance, the interaction of nitrogen oxides with volatile organic compounds under sunlight produces photochemical smog, one of the most dangerous forms of secondary pollution in urban areas.

Anthropogenic pollutants are conventionally divided into primary and secondary pollutants.

Primary pollutants are chemicals that come directly from the source (workplace, livestock farms, motor vehicles, household gas stoves, industrial plants, thermal power plants, boiler houses, burning waste heaps and landfills, storage facilities, storage ponds, stormwater discharges, as well as industrial and domestic wastewater discharges, etc.).

Secondary pollutants are products of transformation of primary pollutants in the environment or products of chemical and photochemical reactions of primary pollutants with each other and with natural factors.

In other words, secondary environmental pollutants are qualitatively new, derived from primary pollutants.

Similarly, the process of environmental pollution can be primary or secondary. In this regard, it would be appropriate to recall the following [2—4].

Anthropogenic pollutants, reacting with each other and with natural chemical components, create secondary pollution of the environment (including air), and thus have a combined effect on all forms of life. It is believed that modern anthropogenic chemical pollution of the environment can disrupt the functioning of the human immune system with consequences that are in some ways similar to those of AIDS.

At the same time, many derivatives of primary pollutants acquire more harmful properties in the process of chemical, biochemical, physical and physicochemical transformation and are able to "live" in the components of the biosphere for a long time. During this time, they can continue to form new combinations and their derivatives with each other and other pollutants.

In other words, secondary pollution is a kind of anthropogenic "chain reaction" whose consequences are impossible to predict both in terms of scale and time, and therefore become one of the decisive environmental factors.

In many cases, the combined effect of pollutants and their derivatives on biota and humans is stronger (the phenomenon of synergism) than the effect of each of them taken in the same concentrations, but separately [5].

The total effect of the same substances on the same type of cell in the body depends on the sequence in which the substances act, as well as the time interval between the effects of each substance and other conditions. That is why in some cases, instead of a synergistic effect, antagonism may occur.

For example, the toxic effect of a number of chemical elements is based on their antagonism with macro — and microelements that are vital for the body's cells. In particular, antagonism is known between Mn and Fe; Ni and Zn; Ni and Mn; Zn and Fe; Zn and Mn; Cu and Zn; Cu and Fe; Cu and Mn; Zn and Mg, Ca, Na, K; Al and Ca, K, Mg; Ni and Co–P, N, Ca, K; Cu and Cd–P, K, Fe, which can result in deficiencies in the body, for example, I, Co and Cu [6].

An example of secondary toxins is nitrosoamines. On the one hand, nitrates, nitrites and nitrogen oxides coming from the outside with air, water, food and medicines (oxytetracycline, amidopyrine, analgin, phenacitin, bromhexine, piperazine, ampicillin, ethambutal, oxacillin, pyramidone, etc.; derivatives of cimetidine — nitrozocimetidine and dinitrozocimetidine have mutagenic properties in addition to carcinogenic ones) and are capable of nitrosation, and, on the other hand, nitrosable agents (amines, amides), which are formed in the body from products of amino acid and protein metabolism or come from the outside.

Thus, the danger of secondary environmental pollution lies in the fact that non–toxic ingredients can, under certain conditions, produce poisonous substances, such as phosgene gas. The transformation of man–made organic compounds is often accompanied by the formation of metabolites — intermediate compounds that possess higher biological activity compared to the original substances. For instance, the transformation of certain pesticides can lead to the appearance of derivatives that are two to ten times more toxic, such as ethylene urea and ethylene urea monosulfide.

Dissolved substances may be converted into other dissolved forms, which increases the migration of harmful pollutants in the environment and along the trophic chain, thereby raising the likelihood of their entry into the human body. The combined impact of phenols, non–toxic dust, ammonia, sulfur dioxide, and nitrogen oxides leads to a reduction in plant productivity, resulting in a shortage of oxygen in the city's ecosystem [7].

Lead and cadmium significantly increase the toxicity of oil hydrocarbons — sometimes by ten to one hundred times. The combined toxicity level of zinc and copper is eight times higher than the toxicity level of each metal when they act separately. Copper, in turn, amplifies the effect of certain pesticides from the dithiocarbamate group (such as nabam, thiram, metiram, zineb, and ferbam), which makes their use unacceptable in regions heavily polluted with heavy metals, especially copper [8].

Nitrates can enhance the effect of many radionuclides by five to six times. A similar effect is observed in the combined influence of radon, lead, ozone, and nitrogen oxides. Many harmful combinations present in the air of large industrial cities also exhibit a summation effect. This is particularly true for combinations like ozone with nitrogen dioxide and formaldehyde, sulfur dioxide with sulfuric acid aerosols or nickel, sulfur dioxide with nitrogen dioxide, phenol with converter dust, and carbon monoxide with cement dust.

The resorption of Pu–239 in the human body proceeds twice as fast when the radionuclide is present in the form of nitrate. If it comes into contact with the skin, a wound, or inhaled air together with tributyl phosphate, this process accelerates four to sixteen times. Some heavy metals can increase both the lethal and carcinogenic effects of radiation. Moreover, lead, ozone, nitrogen oxides, and nitrates intensify the harmful influence of radon on the human body.

It is virtually impossible to imagine the combined biological effects of anthropogenic compounds, their compounds and derivatives. However, the basics of mathematics allow us to calculate the number of combinations for at least seven substances, if each of them is assigned a serial number. That is, determine the factorial of the number 7 (from 1 to 7). We will get 5040 different combinations from the permutation (1, 2, 3, 4, 5, 6, 7, or 1, 3, 2, 4, 5, 6, 7, or 1, 7, 2, 3, 4, 5, 6, etc.) Other examples. Only 7 notes, or rather 7 original sounds and their derivatives (different in length and timbre) have given Mankind, thanks to their various combinations (and how many more will follow!), many unique melodies. Or, thanks to the combination of several dozen sounds (respectively labeled with letters of the alphabet), a person has hundreds of languages and their derivatives.

It is particularly worth mentioning that one of the main types of secondary air pollution in large cities is the formation of conventional and photochemical smog. Ordinary smog represents a thick, opaque fog that arises from the mixing of vehicle exhaust components — such as hydrocarbons, nitrogen oxides, and carbon monoxide (in total up to 1200 components) — with industrial emissions, including aerosols, soot, smoke, and essential oils released by certain plants [4].

Photochemical smog, in turn, is also a dense and opaque fog, but it forms from highly toxic products of photochemical transformations of ordinary smog components. [4] These products include hydrogen peroxide, ozone, nitrogen pentoxide, molecular nitrogen, organic peroxides, and extremely hazardous substances such as peroxyacetyl and peroxybenzoyl nitrates, as well as free radicals and various nitrogen compounds.

Equally important are the environmental problems associated with motor vehicles. Automobiles contribute up to 30 percent or more of the total air pollution in large cities. Vehicle emissions contain fuel vapors and over 500 (sometimes up to 1200) hazardous compounds, including nitrogen oxides, carbon dioxide, carbon monoxide, ozone, aldehydes, ketones, unsaturated hydrocarbons, phenol, nitrogen and sulfur–containing compounds, soot, and more than 40 surfactants with their derivatives. These exhaust components have a profoundly negative effect on the health of people living near urban highways [9].

Carbon monoxide leads to carboxyhemoglobinemia, affects the central nervous system, and disrupts the body's fat, carbohydrate, phospholipid, and vitamin balance — with the developing fetus being especially vulnerable [1]. Benzo(a)pyrene causes intoxication and contributes to the development of various forms of cancer. Ozone destroys living cells, complicates breathing, and causes long–term damage to lung tissue; its toxicity exceeds that of nitrogen oxides, carbon monoxide, and hydrocyanic acid. Sulfur dioxide provokes conjunctivitis, bronchitis, and pneumonia, while high concentrations can result in vision loss as well as dystrophic changes in the liver, kidneys, and heart muscle. Nitrogen oxides cause toxicosis, cancer, congenital anomalies, fibrous bronchitis, inflammation of the upper respiratory tract, tooth enamel destruction, heart failure, and nervous system disorders [10].

It has been proven that the clinical and biochemical profile of blood in people exposed to vehicle exhaust is almost identical to that observed in several well–known diseases. For example, residents living near major highways exhibit changes in the functions of the liver, pancreas, salivary glands, and muscle tissue, which are accompanied by alterations in blood chemistry characteristic of viral hepatitis, pancreatitis, mumps, and various muscle disorders [9].

Physical factors can exacerbate the effects of toxic substances on the human body, and therefore chemical pollution of the urban air environment should be considered separately from chronic noise pollution, which is believed [4] to act on the human body like a cumulative poison (i.e., the negative effects of noise "pollution" accumulate in the body).

In view of the above, it would be appropriate to recall several important facts [4]. Under conditions of prolonged noise discomfort, the body of a young person during puberty suffers the most. After the age of 27, the human body becomes even more sensitive to noise exposure. Each decibel exceeding the permissible noise level reduces labor efficiency by 1 %, increases the risk of hearing loss by 1.5 %, and raises the likelihood of cardiovascular disorders by 0.5 %.

Chronic noise with an intensity of 30 dB and above affects the human psyche; noise levels of 60—90 dB influence both the psyche and the autonomic nervous system; levels of 90—120 dB have the same effects but additionally cause hearing impairment, stomach ulcers, and hypertension; noise exceeding 120 dB directly affects brain cells. Chronic noise can cause discomfort even when its strength corresponds to the sound of an object that can be heard without effort from a distance of 1.5 meters [9].

Noise above 110 dB acts on the human body like a physical drug. Initially, it provokes a state of "noise intoxication" or aggressive excitement, and later leads to the destruction of hearing and brain tissues. A noise level of 150 dB, corresponding to the sound of a gunshot or rocket launch, is considered the maximum threshold for the human body. Beyond this level, a person may experience ringing in the ears, a pronounced sense of fatigue, difficulty swallowing, hearing loss, and drastic changes in hemodynamics (blood composition).

Infrasound — sound waves with a frequency below 20 Hz — is extremely dangerous. Such waves can penetrate even the thickest walls, as their energy is absorbed much less than that of ordinary sounds. Their long wavelength allows them to bypass obstacles and travel vast distances from the source. Because infrasound is almost imperceptible to the human ear, the likelihood of exposure to it is particularly high. It activates the body's energy expenditure, which the person perceives as significant physical exertion, leading to a feeling of extreme fatigue. Moreover, infrasound reduces hearing and causes vestibular, cardiovascular, and central nervous system disorders, sometimes leading to loss of consciousness.

The source of infrasound is powerful engines of vehicles with a rotation speed of 1200 revolutions per minute. In particular, when aircraft such as TU–134, TU–154, and Boeing 727 take off, infrasound with a frequency of 4—20 Hz is generated and spreads over a distance of 80—120 km.

Vibration, unlike sounds, is perceived by various parts and internal organs of the human body, and its energy is mainly transformed into the energy of biochemical and biophysical processes.

Vibration that fluctuates in the infrared spectrum, i.e. below 20 Hz, is particularly dangerous.

The explanation for this is as follows.

From the point of view of physics, the human body is a system of interconnected vibrating elements — individual parts and organs that have their own vibration frequencies: the shoulder girdle, hip and head in a standing position: 4—6 Hz; the abdominal cavity: 4—8 Hz; the head in a sitting position: 20—30 Hz; internal organs: 6—9 Hz.

The coincidence (resonance) of these frequencies with the frequency of external vibration (as well as with the frequency of infrasound) can "disable" vital human organs.

Frequencies have the most negative impact:

- 1—3 Hz (disturb the rhythm and depth of breathing);
- 5 Hz (cause mechanical damage to internal organs);
- 7 Hz (coincides with the L–rhythm of the brain's bio–currents);
- 15 Hz (initiates pain in the chest, abdomen, lower back and some muscles, and prolonged exposure contributes to neuropsychiatric disorders — depression, vague anxiety and unreasonable fear, which even lead to suicidal thoughts).

According to the level of negative impact on the human body, man–made vibration sources are conditionally divided into three groups:

- sources of very low frequency vibration (up to 2 Hz);
- low frequency vibration sources (from 2 to 20 Hz);
- high frequency vibration sources (over 20 Hz).

Both unnaturally loud man–made sounds (gunfire, rockets, airplanes, etc.) and the absence of natural sounds in the conditions of enhanced sound insulation of underground premises (bomb shelters) during prolonged stay in them have a negative impact on the mental state and physical health of people. The latter is explained by the fact that human evolution took place against the background of constant natural sounds (the noise of rain, wind, waves, birdsong, speech, etc.). Noise over 110 dB acts on the human body like a drug. At first, it leads to "noise intoxication" or aggressive excitement, and then to direct destruction of brain tissue and hearing aids. Noise of 150 dB and above leads to a pronounced feeling of fatigue, difficulty swallowing, hearing loss, and a sharp change in the dynamics of blood composition.

Infrasound can spread from man–made sources within a radius of 80—120 km.

Thus, prolonged and chronic noise "pollution" of the air environment causes noise stress in humans — a malfunction of the central nervous system and other body systems due to emotional and physical stress associated with noise discomfort. This stress is considered to be one of the most destructive, as it not only undermines a person's physical and mental health, reduces their ability to work, but also reduces life expectancy by 8—12 years. The body's reaction to noise is quite individual for different people and depends on the degree of mental and physical stress of a particular person, his or her age, health status and other characteristics.

Given the current situation, we can mainly talk about its stabilization, and its improvement will be possible only after the war is over.

Conclusions

Taking into account all of the above, it is not realistic to MANAGE (in the full sense of the word) the air quality of the Dnipro agglomeration in today's conditions. Still, we can suggest some measures that will make it easier to solve the problem at the local level, namely, to protect the health of the citizens whose lives are being fought for by our military defenders at the front.

Adopt a decree (and have the police enforce it) to ban the driving of "golden youth" in vehicles without mufflers, which create noise levels in the evening and at night that in some cases can compete with loud pop music (120 dB), with the noise of jet engines at a distance of 25 meters (130—140 dB), and even with the noise created by a space rocket at launch (150—160 dB) or a cannon shot (170 dB).

Prohibit dry cleaning of the city territory with mechanical means, including those used to "blow" yellowed leaves and grass clippings from lawns in parks and squares. Such "cleaning" contributes to air pollution with fine dust and grass pollen up to a height of 2 m, i.e. the height of an adult, which can pose a threat to allergy sufferers. But children, whose respiratory tract (unlike adults) is closest to the ground, will suffer the most in this case.

These particles adsorb a significant amount of gas molecules — the volume of adsorbed gases is many times greater than the dust's own volume. In particular, at normal temperature and pressure, particles with a total volume of 50 cm^3 can hold up to 2.5 dm^3 of air, turning into chemically active substances. Fine dust is also capable of penetrating the alveolar walls, transferring to the bloodstream a number of dangerous pollutants adsorbed on its surface during exposure to air, including Be, As, Cd, Ni, Pb, Se, Cr, Hg, V, asbestos, and others. Settling on the skin and mucous membranes of the eyes and upper respiratory tract (larynx, nose, trachea, bronchi, lungs), it causes mechanical irritation and inflammation, which eventually lead to dermatitis, eczema, conjunctivitis, rhinitis, catarrh, and bronchitis.

To control plants that cause allergic reactions in people, it is necessary to avoid using certain woody species in green construction. It should be recalled that organic dust — such as pollen from plants (including ragweed) — is almost three to eight times more toxic to humans than mineral dust and becomes even more dangerous when combined with SO_2, which is a common component of the air in industrial cities.

It is important to understand that the lack of sunlight cannot be compensated for even with the most modern artificial lighting equipment, as artificial and natural light are biologically unequal: sunlight (unlike artificial light) maintains the biorhythms of the human body, has a positive effect on the biosynthesis of hormones and on nerve endings, activating metabolic and physiological processes in the body. That is why artificial lighting, even with an intensity of 2000—2500 lux and spectral characteristics as close as possible to the spectrum of sunlight, only approximately creates the biological effect of natural light with an intensity of 500 lux.

In addition, the accumulation of radon and its isotopes in the air in closed underground structures should be controlled, and radon protection should be created under their foundations. Radon (a colorless and odorless radioactive gas) and its daughter decay products provide an average of about 50 % of the radiation background of the premises (here, the main dose is received by a person due to the isotope 222 Rn). The main source of radon is the soil, from where it is drawn in (the "chimney effect" arising from the difference in external and internal pressure and temperature) through microcracks in the concrete (or other material) of the building, and the main way it enters the human body is through the upper respiratory tract.

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ЗАХОДИ ЗІ ЗМЕНШЕННЯ ЗАБРУДНЕННЯ ПОВІТРЯ В МІСТАХ В УМОВАХ ВОЄННОГО СТАНУ НА ПРИКЛАДІ МІСТА ДНІПРО

Реферат

У статті розглянуто актуальні виклики щодо зниження забруднення повітряного середовища міст в умовах воєнного часу на прикладі м. Дніпро. Проблема посилюється через вибухи, пожежі, техногенні аварії, а також додаткові викиди від промислових підприємств і автотранспорту.

У дослідженні було проведено глибокий аналіз джерел як первинних, так і вторинних забруднювачів атмосферного повітря. Особливу увагу приділено оцінці трансформаційних процесів у довкіллі, під час яких відбувається утворення токсичних продуктів хімічного чи фотохімічного походження. Окрім цього, розглянуто вплив шумового та інфразвукового забруднення на організм людини, що дало змогу визначити комплексний характер антропогенних навантажень на здоров'я населення.

Проведений аналіз показав, що первинні забруднювачі — промислові викиди, вихлопи автотранспорту та наслідки вибухів — у процесі хімічних і фотохімічних реакцій трансформуються у вторинні забруднювачі, які нерідко мають вищу токсичність і триваліший вплив на довкілля. Дослідження також засвідчило комбінований вплив токсичних речовин і фізичних чинників, таких як шум та інфразвук, що значно підсилює їх негативний ефект на стан здоров'я населення. Виявлено наявність синергетичного ефекту між окремими сполуками, внаслідок якого збільшується загальна токсичність середовища та ризики для екосистем.

Для мінімізації наслідків забруднення запропоновано комплекс практичних рішень. Одним із ключових напрямів є запровадження жорсткого контролю за промисловими викидами, особливо у нічний час, коли спостерігається зниження інтенсивності розсіювання шкідливих речовин. Важливим є також обмеження шумового забруднення шляхом регулювання руху автотранспорту у межах міста. З метою зменшення кількості дрібнодисперсного пилу рекомендується відмовитися від сухого механічного прибирання територій, замінивши його зволоженим або вакуумним очищенням.

Окрему увагу приділено боротьбі з алергенними рослинами, зокрема амброзією, шляхом їх локального знищення та запобігання подальшому поширенню. Для підвищення безпеки населення у бомбосховищах запропоновано організувати ефективну вентиляцію та здійснювати контроль рівня радону, що є важливим елементом захисту у воєнний період.

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